[COMMITTEE PRINT]

REVIEW OF SPACE SHUTTLE REQUIREMENTS, OPERATIONS, AND FUTURE PLANS

REPORT

PREPARED BY THE

SUBCOMMITTEE ON

SPACE SCIENCE AND APPLICATIONS

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LETTER OF SUBMITTAL

U.S. House of Representative
Committee on Science and Technology
Subcommittee on Space Science and Applications

Hon. Don Fuqua, Chairman
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

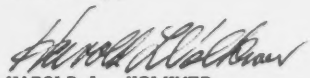
In the past three years, the Space Shuttle has demonstrated that it is a truly versatile and reliable Space Transportation System. On the other hand, much work remains to be done if the system is to successfully accomplish NASA's goal of achieving full operational maturity by 1989.

Accordingly, the Subcommittee on Space Science and Applications held three-days of hearings on July 31, August 1, and August 2, 1984 to conduct a thorough review of Space Shuttle requirments, operations, and future plans in order to assure that the system will continue to evolve into an efficient, responsive, and cost-effective Space Transportation System.

This reports summarizes the witness testimony, which is published as a separate document, discusses key issues raised during the hearings, and presents the Subcommittee's conclusions and recommendations.

These hearings were organized and the accompanying report prepared by Dr. Harry S. Dawson, Jr., of the Subcommittee staff. I commend the conclusions and recommendations to your attention.

Sincerely,



HAROLD L. VOLKMER
Chairman, Subcommittee on
Space Science and Applications

CONCLUSIONS AND RECOMMENDATIONS

After analyzing all of the testimony and views that were offered at the hearings, the Subcommittee has reached a number of conclusions and where appropriate, made related recommendations.

1. NASA has made considerable progress in establishing long-term goals and objectives for various Space Shuttle elements which, if successfully accomplished, should bring the Space Transportation System to full operational maturity by 1989.

The Subcommittee recommends that these goals and objectives, as well as their related implementing plans, continue to receive high-level management attention within the agency and be updated and revised (at least over the next several years) on an annual basis.

2. The Subcommittee commends NASA's appointment of a Shuttle Operations Strategic Planning Group to conduct an indepth analysis of the extent to which Shuttle operations can be "fenced" (i.e., clearly separating the personnel, budgets, and facilities that support Space Shuttle operations from the rest of NASA's programs) and if and when these operations should be permanently "spun-off" to an outside organization. Additionally, the Subcommittee was impressed with the arguments that NASA should "go slow" in rigidly fencing Shuttle operations (especially its personnel) while a significant level of research and development work is underway.

If Shuttle operations are to be transferred to an outside organization, such factors as the high government utilization of the system, the importance of the Shuttle to key NASA programs (such as the Space Station), and national security issues must be considered. These considerations may lead to a conclusion that Space Shuttle operations should either be retained within government (in either NASA or some other agency) or transferred to a quasi-government corporation, rather than being transferred to a private company.

The Subcommittee recommends that, although it supports the concept of fencing Shuttle operations, NASA should move cautiously with efforts that would either rigidly fence Space Shuttle operations inside of NASA or result in the transfer of Shuttle operations outside of NASA.

3. Logistics management responsibilities for various elements of the Space Transportation System are currently shared by three different NASA field centers (i.e., Johnson Space Center, Marshall Space Flight Center, and the Kennedy Space Center). Management efficiency would be improved if these responsibilities were consolidated at a single field center.

The Subcommittee recommends that NASA move expeditiously in consolidation of STS logistics management responsibilities at a single NASA field center.

4. The Subcommittee agrees with the proposal that is under review within NASA that the agency begin to differentiate in its operating budgets between available STS capacity and actual demand. This differentiation will permit the Congress to more readily distinguish between these two parameters and will also alert customers when unused STS capacity is available.

5. Based on testimony before the Subcommittee, there generally is unanimity of opinion between the user community and NASA's advisory panels that NASA should continue to provide users with expendable launch vehicle (ELV) launches until the Space Shuttle becomes fully operational. The concerns of users are based on conservative business attitudes and an apparent lack of full confidence that the Space Shuttle will always be able to support user needs in a timely fashion. Achievement of full operational maturity by 1989 should serve to mitigate user concerns about eventual dependence on the Space Shuttle without the availability of an ELV backup.

The Subcommittee recommends that the goal of achieving full operational maturity for the Space Transportation System continue to be one of the highest priority objectives of NASA.

6. The Subcommittee believes that an ELV employing Space Shuttle hardware and technology could be developed to meet the Defense Department's national security needs for a "complementary" launch vehicle. The Subcommittee urges the Defense Department to give this approach equal and fair consideration. Additionally, the Subcommittee urges the Defense Department to give special consideration to those vehicle alternatives that will be capable of supporting payload growth requirements anticipated in the foreseeable future.

7. The full extent of the financial and programmatic impact on the Space Transportation System of continued ELV use by the U.S. Government or the commercial sector is insufficiently understood to allow fully informed policy determinations on this matter.

The Subcommittee recommends that NASA conduct a thorough assessment of the effect of government and commercial use of ELVs on the Space Shuttle program. This assessment should enumerate the specific circumstances, if any, under which ELV use would have an effect on the cost-effective employment of the Space Transportation System.

8. The Subcommittee continues to believe that the Space Shuttle should and will be the primary launch vehicle used by the United States. However, if the broadest perceived needs (including ELV use) of the user community can be accommodated without severe impact on the cost-effectiveness of the Space Transportation System, NASA need not resist the efforts of users to fulfill these perceived needs.

9. All STS users who testified before the Subcommittee expressed the view that NASA has been working hard to respond actively and positively to their concerns in order to make the Space Shuttle more responsive and accommodating to user needs and requirements.

The Subcommittee recommends that NASA continue to seek and respond to user input concerning needed Space Shuttle improvements.

10. Members of the user community expressed concern about the adequacy of the design, manufacturing, and testing oversight associated with propulsion systems provided by the private sector.

The Subcommittee recommends that the Administration give serious consideration to the proposal made by civil users that the government institute an independent and continuous review of the design, manufacture, qualification, and test of all propulsion systems produced within the United States--in essence "certifying" these systems for civil and foreign users. However, if this proposal is adopted, caution should be exercised to ensure that this initiative incorporates a minimum amount of regulatory activity. NASA, in cooperation with other appropriate agencies, is requested to provide a report to the Subcommittee by April 15, 1985 regarding if, when, and to what extent this proposal will be adopted.

11. NASA has made significant progress in reducing Space Shuttle turnaround time from a high of over 100 workdays to a current low of 53 workdays. Further, NASA's short-term turnaround goal of 35 workdays and long-term turnaround goal of 28 workdays appear reasonable and achieveable. However, the experience of the last Space Shuttle mission (41-D) demonstrates the delaying effect that current time requirements to compile and verify each mission's computer software package can have on a Shuttle flight when the payload manifest must be quickly changed.

The Subcommittee recommends that NASA continue to give high priority to achieving its goals of reducing Space Shuttle turnaround time and that the agency devote special attention to substantially reducing the amount of time needed to compile and verify the computer software package required for each mission, or in some way eliminating the need for a new software package for each flight.

12. NASA has made considerable progress in reducing the cost of Space Shuttle operations and has plans to further reduce these costs. The Subcommittee encourages these efforts but cautions that NASA continue to exercise vigilance to assure that the efforts to achieve cost reductions do not reduce system reliability and safety levels.

13. The Shuttle pricing policy debate has become an emotionally charged issue revolving primarily around a discussion of Shuttle competition with efforts to privatize expendable launch vehicles.

In addition to cost, the Shuttle pricing policy should consider the following factors:

(a) the long-range goal of greatly increasing commercial space activities using Shuttle-unique capabilities,

(b) stability and predictability of government policies,

(c) competition with domestic efforts to privatize or develop expendable launch systems,

(d) competition with foreign launch systems for both international and domestic payloads,

(e) the interests of industries that have already made significant investments to enhance and utilize the Space Shuttle.

The Subcommittee believes that the pricing policy that most brings into balance the needs of both the government and the user community is to base user charges on additive cost. The Subcommittee is concerned that the adoption of a pricing policy (such as total cost recovery) that results in a price significantly above the current price of $71 million per flight (in constant FY 1982 dollars) could do substantial harm to the continuing programmatic and economic viability of the Space Shuttle program.

14. During the hearings, civil users suggested a number of changes related to pricing policy that would make the Space Shuttle more attractive to the commercial sector:

- o Price changes should be more frequent (e.g., annually) but smaller,
- o Flight prices should be set each year and then that price (adjusted for inflation) should hold for all launch agreements formally signed in that year, irrespective of when the launch is scheduled to occur,
- o Users should be provided with (non-binding) price projections for 10 to 15 years in the future,
- o Accommodation should be made for deferred payments,
- o Postponement penalities should be reduced,
- o Standby payload discounts should be increased, and
- o Consideration should be given to offering more than one class of fare.

The Subcommittee believes that these suggestions could have merit but realizes that additional scrutiny is required to determine the specific advantages and disadvantages of each suggestion.

The Subcommittee recommends that NASA thoroughly review these suggestions and then adopt those which the agency believes will be beneficial. NASA is requested to provide a report to the Subcommittee by April 15, 1985 on which of these suggestions are appropriate to adopt.

15. The Air Force testified that it will not be unusual for DOD to cancel scheduled Space Shuttle flights when satellites which had been predicted to fail by a certain timeframe are found still to be fully operational. This situation can cause NASA to incur expenses for which it is not compensated by the Defense Department. Also, should NASA adopt total cost recovery as a basis for the price charged commercial users, uncompensated DOD cancellations could cause user prices to increase.

The Subcommittee recommends that NASA reach an agreement with the Defense Department that will require DOD to be assessed a non-refundable "standby charge" when it reserves a flight on the Space Shuttle manifest. This charge should roughly equal the non-recoverable expenses that NASA incurs in scheduling and preparing for a flight.

16. The Subcommittee continues to see a need for a fifth Orbiter. This position is all the more significant in that the hearing indicated a replacement system for the Space Shuttle (i.e, the Shuttle II) may not be available for 20 to 25 years and that it is questionable whether "replenishment" Orbiters will be built in the meantime.

If the initiation of construction of the fifth Orbiter is delayed beyond FY 1986, the loss of prime and second-tier contractors may make the vehicle prohibitively expensive to produce at a later date.

The Subcommittee recommends strongly that NASA reach a final decision on the procurement or non-procurement of the fifth Orbiter as a part of its FY 1986 budget decision process.

17. The Subcommittee supports NASA's planned improvements in Space Shuttle components that will extend their useful lives, improve their reliability, reduce their turnaround time, or reduce their unit cost. However, some users foresee need for improvements in the Orbiter's inherent capabilities that are not broadly supported within NASA.

The Subcommittee recommends that NASA place higher priority on making improvements in the Orbiter's capabilities (such as available electrical power, on-orbit lifetime, and on-orbit maneuver propellants) which will be needed to support Space Station, Space Telescope, materials processing, and other significant activities.

18. The future development of a second generation Space Shuttle offers the potential for significantly reducing the cost of routine space transportation operations by as much as a factor of ten and decreasing ground turnaround times to as little as one week.

The Subcommitteee recommends that NASA actively pursue the development of the technologies that appear promising for the future development of a second generation Space Shuttle. At a minimum, this will include technology developments in the areas of structures and materials, propulsion, and aerodynamics.

19. The Subcommittee recognizes the critical importance of an adequate supply of repair and replacement parts and a healthy logistics support infrastructure for the Space Shuttle to achieve full operational maturity. Accordingly, the Subcommittee is pleased with the emphasis that NASA has placed in the past year on permanently resolving STS logistics problems.

The Subcommittee recommends that NASA continue to give a high level of priority to resolving STS logistics problems and to maintaining an adequate reserve of spare parts and a viable logistics base required to supply them.

20. The Subcommittee agrees with NASA officials that maintaining flight safety should remain the highest priority of the Space Shuttle program. Additionally, the Subcommittee believes that NASA should continue to develop and maintain adequate safeguards to ensure that a long record of success does not lull contractors and program officials into "letting their guard down" and allowing process controls and quality controls to lapse.

The Subcommittee recommends that NASA continue its past efforts to treat flight safety issues as the highest priority aspect of the STS program.

21. Aside from the top priority of safety and cost, the Subcommittee believes that NASA should continue to examine conflicting priorities of lesser importance such as minimizing turnaround times and schedule delays while attempting to maximize system flexibility and ease of user access.

I. INTRODUCTION

Now that the Space Shuttle has completed its research and development phase as well as the initial stages of its program to achieve full operational maturity, the Subcommittee felt that a thorough review of Shuttle requirements, operations, and plans was necessary to assure continued evolution of the program into an efficient, responsive, and cost-effective Space Transportation System. Accordingly, three days of hearings were held on July 31, August 1, and August 2, 1984, with witnesses drawn from the National Aeronautics and Space Administration (NASA), Department of Defense (DOD), NASA Advisory Panels, and the civil users community.

In his opening statement, Chairman Volkmer praised the progress that has been made to date in the Space Shuttle program, but observed that:

> "As we look to the future, it is clear that major improvements are going to have to be made in the manner in which missions are planned, formulated, and executed, and the speed with which flight equipment can be readied for their next use. These improvements are essential if the program is to be able to achieve the steady-state operations envisioned for the late 1980s and thereafter. At the same time, program managers will have to be vigilant to ensure that initiatives to reduce time lines and operating costs do not jeopardize the excellent quality control levels and flight safety records that have characterized the Space Shuttle program."

Congressman Lujan, the Ranking Republican Member of the Subcommittee, added in his opening statement:

> "This hearing is an important milestone in the Space Shuttle program. Although the Space Shuttle is no longer strictly a research and development program, it also is not yet fully operational. So, as we look at the requirements for the next phase of the Shuttle program, we will first need knowledge of what the present status is--both the problems and the successes. In addition, a successful transition will require a consensus as to what we want the future to be for the Space Shuttle."

The hearings focused on the following major issues:

- Has NASA developed adequate plans to ensure a successful transition of the Space Transportation System to full operational maturity?

- Should Space Shuttle ownership and operations be "spun-off" to the private sector?

- How realistic are current launch manifest projections for the Space Shuttle?
- Should the U.S. Government continue to use expendable launch vehicles?
- How adequately will the STS be able to satisfy user requirements?
- How will Shuttle operating costs and turnaround times be reduced?
- What should the Shuttle's pricing policy be for the future?
- Should additional Orbiters be procured?
- What future improvements should be made in the Space Shuttle?
- When might a next generation Space Shuttle become available?
- How will the Shuttle's current logistics difficulties be resolved? and
- How will the Shuttle's past flight safety record be maintained?

II. BACKGROUND

In his opening statement Mr. Volkmer observed that "since its first research and development flight three years ago the Space Shuttle has demonstrated its flexibility, reliability, and an ever-growing performance capability." Mr. Beggs added in his opening remarks that "the Space Shuttle has demonstrated that it is the most reliable space transportation vehicle ever built."

In just a few years, the Space Shuttle has demonstrated its ability to:

- o Handle an ever growing launch rate,
- o Accommodate payloads that are growing in number, weight, and complexity,
- o Reconfigure readily the composition of its payload manifest to respond to unforeseen circumstances,
- o Launch and land under nighttime conditions, and land at a variety of locations,
- o Accommodate an increased number of crew members onboard the Orbiter and days spent on orbit,
- o Recover and repair damaged spacecraft on orbit, and
- o Support the accomplishment of important space science, materials science, and medical experiments.

Additionally, substantial improvements have been made in the technical performance and unit cost of major STS components:

- o Orbiter weight has been reduced; production man-hours have declined by almost 30 percent; mission turnaround time has been reduced from a high of over 200 workdays to a current low of 53 workdays, and the necessary improvements are in place to soon achieve a 35 workday turnaround time,
- o External tank weight has been reduced by 8,000 pounds, and unit production cost has been reduced by 43 percent from the 8th unit to the 15th unit produced,
- o Solid Rocket Booster improvements (including weight reductions and performance enhancements) have thus far produced a Shuttle payload capability increase of 4,400 pounds, while the Filament Wound Case motor now in development will further increase this to 8,400 pounds, and unit cost has been reduced by 31 percent from the 6th unit produced to the 15th unit produced,

- o Space Shuttle Main Engine performance has been increased by about 5 percent; the flight lifetime certification for the overall engine has been increased to 10 flights; and improvements are underway to substantially increase the lifetime of individual components (such as high-speed turbo machinery) that have been experiencing excessive wear-out rates, and

- o Hardware and process improvements have been made that have reduced from 36 months to 22 months the amount of time required to integrate mission payloads.

Clearly, the Space Shuttle's record thus far has been truly impressive. These accomplishments are especially significant considering that the Space Shuttle is the most complicated and technologically advanced manned-spacecraft ever flown.

III. Summary of Testimony

The witnesses that testified before the Subcommittee represented a diverse group drawn from NASA, DOD, two NASA advisory panels, and the civil users community. The specific individuals that appeared at the hearings are as follows:

From NASA Headquarters:

Hon. James M. Beggs
Administrator
National Aeronautics and Space Administration

Jesse W. Moore
Associate Administrator for the Office of Space Flight
National Aeronautics and Space Administration
Accompanied by:
L. Michael Weeks
Deputy Associate Administrator (Technical)

Isaac T. Gillam, IV
Assistant Associate Administrator (Customer Relations and Policy)

Charles R. Gunn
Director, Shuttle Operations

From DOD:

Hon. Edward C. Aldridge, Jr.
Under Secretary
Department of the Air Force

From NASA Field Centers:

Gerald D. Griffin, Director
Lyndon B. Johnson Space Center
Accompanied by:
Glynn S. Lunney, Manager
National Space Transportation System Program Office

Dr. William R. Lucas, Director
Marshall Space Flight Center
Accompanied by:
Robert E. Lindstrom, Manager
Shuttle Projects Office

Richard G. Smith, Director
John F. Kennedsy Space Flight Center
Accompanied by:
Tom Utsman, Director
Shuttle Management and Operations

Dr. Donald P. Hearth, Director
Langley Research Center
Accompanied by:
Paul Holloway, Director for Space

From NASA Advisory Panels:

William A. Anders, Member
NASA Advisory Council

John G. Stewart, Member
Aerospace Safety Advisory Panel

From Civil Users Community:

John Almond
Vice President
Telesat Canada, Limited

Michael T. Lyons
Vice President
Space Segment Engineering and Operations
Satellite Business Systems

F. William Ziegler
Executive Consultant
Western Union Telegraph Company

Robert E. Pace, Jr.
Vice President
Microgravity Research Associates, Inc.

R. Gilbert Moore
Program Development Manager for Space Shuttle Programs
Morton-Thiokol, Inc.

The following is a brief summary of each witness' testimony:

Hon. James M. Beggs. Mr. Beggs testified that the Space Shuttle has the capability to satisfy all presently projected foreign, commercial, DOD, and NASA launch requirements for years to come and will provide the Nation with a capability to commercialize space. Mr. Beggs also stated that NASA would develop a framework and policy for the organization and management of future STS operations. A Shuttle Operations Strategic Planning Group will be established by NASA to devise this framework and policy, including options that would allow segregation of Shuttle operations within NASA. Mr. Beggs felt that even though Shuttle development efforts would continue through 1988, NASA would be able to report to the Committee by late 1986, on options to turn Shuttle operations over to a quasi-government organization or to transfer it to the private sector.

In the meantime, NASA will focus on bringing the STS to operational maturity. This effort will involve making modifications to the Orbiter fleet, improving life and operating margins on the main engines, improving production output on the External Tank and Solid Rocket Boosters, assisting STS operations at Vandenberg Air Force Base, and providing enhanced customer support for Shuttle and Spacelab users.

Mr. Jesse W. Moore. Mr. Moore provided a detailed assessment of development activities, performance experience, and operations planning associated with the Space Shuttle. He stated that NASA's primary goal for the Shuttle system is to make it fully operational and cost effective in providing routine access to space for all users. In addition, NASA is working to reduce costs, improve quality and safety, increase productivity, ensure customer satisfaction, and enhance commercial opportunities in space as they relate to the STS. Specifically, over the next five years NASA plans to increase the Shuttle flight rate to 24 flights per year by 1989, improve the operational life of the Shuttle Main Engine by extending turbopump operating lifetimes, improve the Shuttle's ability to land at the Kennedy Space Center (KSC) on a routine basis, and activate launch pad B at KSC and the Vandenberg Launch Facility by October 1985.

At present, Shuttle manifesting is being adversely affected by problems with solid rocket upper stages available to Shuttle users, specifically the Payload Assist Module (PAM) and the Inertial Upper Stage (IUS). Mr. Moore reported that these problems appear to have been identified and corrected and that the IUS will be available to deploy TDRS-B in February, 1985. Despite these corrections, upper stage problems have demonstrated fundamental deficiencies in solid rocket technology. NASA will establish a program at the Marshall Space Flight Center (MSFC) to respond to this generic problem.

In the area of Shuttle processing, NASA is working to achieve a turnaround capability of 35 workdays needed to support a launch rate of 20 flights per year at KSC. NASA's long term goal is to achieve a 28 day turnaround capability.

Capability enhancements are also underway for Shuttle hardware and include development of an improved Shuttle Main Engine and a lightweight Filament-Wound Case (FWC) for the Solid Rocket Boosters. These improvements will be completed in time to support the first Vandenberg flight in October 1985 and to launch Galileo (a 65,000 pound payload) in May 1986.

Mr. Moore assured the Subcommittee that there are no outstanding issues that preclude safe Shuttle missions. NASA has experienced continuing problems with the Shuttle's brakes and waste disposal system but steps have been taken to rectify them.

Logistics support for the Shuttle is another area of concern mentioned by Mr. Moore. NASA now has a spares program in place with adequate funds and manpower. However, the agency is concerned that after delivery of the last Orbiter (Atlantis) in April 1985, logistics management and support of the Orbiter fleet will become difficult as vendors

phase down their deliveries of spares. In response to this situation, NASA will centralize Orbiter repair and maintenance at KSC and transfer management responsibility for logistics support to Kennedy when operational maturity is achieved.

Finally, Mr. Moore discussed the organization and management structure for future STS operations. He reiterated Mr. Beggs' announcement that NASA is formulating a task force on Shuttle Operations Strategic Planning. The task force will develop a timetable (as requested in the Subcommittee's FY 1985 Authorization Report--House Report #98-629) for "fencing" Shuttle operating budgets, facilities, and personnel from other NASA activities, and will address possible organizational options (including divesture to a Government or commercial corporation) for STS operations.

Hon. Edward C. Aldridge, Jr. Under Secretary Aldridge's testimony focused on those aspects of DOD's space program that relate to the Space Shuttle. These topics included Air Force plans to bring the Vandenberg launch site to operational status, the adequacy of the Shuttle to meet DOD needs, and the Air Force's plan to acquire an expendable launch vehicle to serve as a complement to the Shuttle.

Under Secretary Aldridge reported that the Vandenberg launch site is near completion and is on track to support an October 1985 first launch. Construction is essentially complete and ground system tests were begun in May 1984. These tests have proceeded well with no significant problems identified according to Under Secretary Aldridge. Facility testing with flight hardware is scheduled to begin in November 1984. Orbiter 103, Discovery, will arrive at Vandenberg in May 1985 for processing.

In discussing Shuttle performance, Under Secretary Aldridge stated that DOD requirements appear achievable for launches from KSC. DOD, however, is concerned with lift capability for launches out of Vandenberg. Upgrading the Shuttle Main Engines to 109 percent power and using Lightweight Filament-Wound Cases in the Solid Rocket Boosters should provide the lift capability required by DOD in the near term.

On the subject of Air Force ELVs, Under Secretary Aldridge said that DOD has unique requirements for assured space launch capability that cannot be satisfied by the Shuttle alone. To meet these requirements, DOD proposes to acquire a complementary ELV system. DOD holds that ELVs together with the Shuttle will provide the U.S. with the flexibility and confidence to launch national security payloads over the long term. According to Under Secretary Aldridge, additional Orbiters alone would not satisfy DOD requirements or relieve DOD concerns.

The Air Force ELV plan calls for development and production of 10 ELVs based on existing technology for use between FY 1989 and FY 1993. DOD would fly two Shuttle class payloads (10,000 pounds into geosynchronous orbit using a Centaur class upper stage) per year on this ELV. A request for proposal has already been issued for this procurement.

DOD is also looking to satisfy a long term requirement for ELV lift capability of 100,000 to 250,000 pounds to low-earth orbit. This capability coincides with requirements of the Strategic Defense Initiative. Funding was requested in the FY 1985 budget to begin requirements definition for this heavy lift booster. DOD does not believe their near-term ELV program, based on known requirements, should be deferred to begin a heavy lift booster development based on unknown requirements.

Gerald D. Griffin. Mr. Griffin described the evolution of the Space Transportation System in five phases: (1) Orbital Flight Test (through STS-4) which certified the adequacy of the basic Shuttle design; (2) Payload Capability Demonstration which is intended to verify the STS capability to meet the requirements of different users in deploying, retrieving, and repairing payloads; (3) System Deployment which involves Orbiter modifications and development of upper stages; (4) Flight Rate Buildup to a steady state of 24 flights per year; and (5) STS-Space Station Operations which is the next extension into space. Mr. Griffin emphasized a need for standard design practices and common procurement for both the Shuttle and Space Station as a way to maintain cost and schedule goals and provide a common logistics infrastructure. JSC, in an effort to streamline STS organization and management, plans to consolidate contracts supporting flight equipment processing activities and the Operations Directorates and to reorganize Space Shuttle project offices.

Dr. William R. Lucas. The Marshall Space Flight Center (MSFC) has management responsibility for development and production of the Solid Rocket Booster (SRB), the External Tank (ET), and the Space Shuttle Main Engine (SSME). MSFC is also responsible for determining launch processing requirements, certifying readiness and assessing flight performance, delivery of flight hardware and spares, and refurbishment of the SRBs and SSMEs.

Dr. Lucas reported that for both the SRB and ET, delivery is on or ahead of schedule, cost per unit has been reduced beyond cost reduction goals, and performance improvements are better than expected. Dr. Lucas attributes these and planned future successes to increased learning from repetition, productivity improvements, and incentive contracting.

The SSME is qualified to operate at a 109 percent thrust level. Improvements are underway to extend the life of engine components, especially the turbomachinery which have failed to meet their design life span. Operational costs and maintenance turnaround times will be reduced with these improvements. Shortage of engine spares has delayed testing and certification of needed production improvements. Nevertheless, Dr. Lucas believes this situation will be rectified in time to support a 24 per year flight rate in FY 1989. Implementation of an SSME incentive contract similar to the production contracts for the SRB and ET is planned.

Richard G. Smith. The Kennedy Space Center (KSC) is primarily responsible for STS launch operations and flight hardware processing. Mr. Smith described the Shuttle processing operations performed under contract to Lockheed. He reported cost savings as a result of the consolidated Base Operations Contract of 14 percent in 1983 with similar savings projected for this contract and the Shuttle Processing Contract in future years. Moreover, Mr. Smith stated that consolidation of facilities, integration of launch site activities, and introduction of new operational concepts and management systems will reduce processing time at KSC to 35 days within a year and 28 days by FY 1987. This processing time will allow a launch rate capacity of 20 per year at KSC by FY 1987 and an additional 4 launches per year at Vandenberg by FY 1989.

Dr. Donald P. Hearth. Dr. Hearth focused his testimony on technology planning for the next generation Space Shuttle. He said the goal for the next Shuttle would be to provide a major advancement in Earth-to-orbit transportation efficiency through lightweight structures and high performance engines; productivity advancements through rapid turnaround and reduced manpower; and cost reductions for all program phases through reusability, long life and increased use of automation in design and manufacturing as well as in operations. The most likely configuration would be winged vehicles resembling current Orbiters, which would take off vertically and land horizontally, and utilize all liquid rocket propulsion. Other configuration concepts were described by Dr. Hearth. He advised continued support to identify, plan, and develop critical technologies for the next major step in space transportation from which the Nation will undoubtedly benefit.

William A. Anders. Mr. Anders presented findings of two recent NASA Advisory Council studies--the study of "Effective Shuttle Utilization" which made recommendations on Shuttle operations, utilization, policies and marketing and the "Mission of NASA" study which examined options for long-term management of the Space Transportation System (STS).

In the "Effective Shuttle Utilization" study, the NASA Advisory Council recommended that NASA continue ELV operations until the STS becomes fully operational and that NASA offload ELV compatible payloads from Shuttle to ELVs to provide a transitional market for commercial ELVs. The Council also recommended measures to make the Shuttle more "user friendly" and actions to improve Shuttle maintenance and spares programs. Increased funding and operational support for space-related research and development and a Shuttle pricing policy that stimulates private investment and new uses for space transportation were urged. A "go slow" approach on STS privatization and an enhanced Shuttle marketing effort were also advised.

Included among the recommendations of the "Mission of NASA" study was one that NASA create a new organization to manage STS operations with supporting manpower, finances, and facilities "fenced" off from the rest of NASA's programs. The Council stated that this new organization should not undertake development activities but should focus on operations with an emphasis toward enhancing customer services and market

development. The study also recommended consideration of a Shuttle pricing policy based on "incremental cost".

John G. Stewart. Mr. Stewart's testimony focused on safety-related issues that the Aerospace Safety Advisory Panel (ASAP) believes will confront the Shuttle program as the flight rate increases and operational status improves. Safety issues of concern to ASAP included STS production quality, reliability of the solid rocket motor on the SRBs, Orbiter structural adequacy, sufficient spares for the Orbiters and Space Shuttle Main Engines, upper stages, Orbiter brake problems, and flight control during landing. In the view of ASAP, however, these issues do not preclude conducting safe Shuttle missions and are being addressed adequately by NASA.

John Almond. Mr. Almond stated that as a customer of launch services, Telesat Canada primarily considers schedule, reliability,and total cost to final orbit when making decisions to procure launch services for its communications satellites. Telesat is especially concerned about launch cost because of the continuing competitive pressure communications satellite services are facing from terrestrial technologies. Mr. Almond said ELVs have an advantage over the Shuttle in this regard because they are dedicated vehicles with shorter lead times, less documentation, simplier satellite interfaces, fewer and less complex vehicle systems, and no special training requirements. Despite these advantages of ELVs, Telesat has booked five Shuttle launches because of its price advantage over ELVs. Mr. Almond commented that STS has demonstrated unexpected improvements in flexibility that are appreciated by customers. He urged maintaining the Shuttle's price advantage and suggested that NASA assume responsibility for providing upper stages for commercial customers as a way to reduce customer obligations.

Michael T. Lyons. Mr. Lyons described Satellite Business Systems' experience in launching their communications satellites on expendable launch vehicles and the Shuttle. While SBS manpower demands are greater for the more complex Shuttle launches compared to ELVs, they become less so as experience is gained with each Shuttle mission. SBS regards the Shuttle as an excellent carrier for communications satellites with a higher reliability compared to ELVs. Nevertheless, for conservative business reasons, SBS has contracted with Arianespace for launch services in late 1986. Because the Shuttle is constrained by an overriding concern with crew safety that may result in lengthy launch delays, SBS wants to gain experience with alternative launch systems to ensure responsiveness to customer demand for its service. Finally, with respect to improving Shuttle operations, Mr. Lyons urged efforts to standardize launches which would result in simplified documentation, shortened processing times, reduced mission complexity, flexible payload manifesting, higher Shuttle utilization, and more economical missions.

F. William Ziegler. Mr. Ziegler described Western Union's experience with space launches. Based on this experience, Western Union recommended: (1) review of safety requirements and payload processing operations to reduce customer burdens without compromising crew and Orbiter safety; (2) changes in relaunch provisions of the Launch Services Agreement to allow customers greater flexibility in decisions to deploy

their satellites (the current provisions impose too long of a relaunch delay and are too expensive); (3) centralizing Shuttle operations at KSC to simplify customer operations and coordination problems; and, (4) changes in Shuttle prices at smaller but more frequent increments. Mr. Ziegler also expressed concern over numerous propulsion system failures (e.g., Inertial Upper Stages, Payload Assist Modules, etc.) and recommended an independent Government review process to address this situation.

Robert E. Pace, Jr. Mr. Pace argued for lower Shuttle prices and more Federal funding for scientific experimentation in space. Without such support, Mr. Pace said that the cost of space products could be so high that the market for these products would be severely inhibited. He also urged Shuttle modifications to extend its mission duration to twenty days and efforts to make STS more "user friendly". While Mr. Pace supported the recently announced "National Policy on the Commercial Use of Space," he opposed government seed money and loan guarantees as a means to implement this policy.

R. Gilbert Moore. Mr. Moore described the Getaway Special program for the Shuttle Student Involvement Project (SSIP), the Long Duration Exposure Facility (LDEF), and the Hitchhiker program. He endorsed these Shuttle utilization programs because they represent the only access to space for many small domestic and foreign users. Mr. Moore also described and supported efforts to develop small, ejectable payloads for the Shuttle. The need to ensure flight opportunities is paramount for space development according to Mr. Moore.

IV. MAJOR ISSUES

During the three days of hearings a number of major issues were addressed by the Members of the Subcommittee and by the witnesses that testified. This section summarizes the principal data and views that were presented on each issue. The issues are organized by topical area, with one or more issues discussed under each topic. The information presented here is drawn from both the testimony given at the hearings and the witnesses' responses to followup written questions posed by the Subcommittee Members.

A. Long-Term Plans

In his testimony, Mr. Beggs stated that NASA has a well established planning procedure, both for the short-term and for the long-term. The long-term plans look at a five-year time horizon and involve the preparation of financial as well as operating plans.

Mr. Beggs indicated that NASA's planning during the next few years will focus on bringing the STS to operational maturity. According to Mr. Beggs, this effort will include:

- Making essential modifications to the Orbiter fleet (such as strengthening the wings of OV-103 and OV-104, and modifying OV-99 and OV-104 to accommodate the Centaur upper stage),
- Improving the life and operating margins on the main engines, particularly the high pressure pumps,
- Implementing production rate buildups and manufacturing process improvements on the External Tank and the Solid Rocket Booster,
- Ensuring that an improved operational capability (both in terms of launch rate and payload lift capability) is in place in the next three years,
- Strengthening NASA's partnership with the Defense Department and helping DOD prepare for manned space operations at both Vandenberg Air Force Base and the Shuttle Operations and Planning Center in Colorado Springs, and
- Providing for Shuttle and Spacelab users increasingly efficient and "customer-friendly" operations.

Mr. Beggs, Mr. Moore, and the Center Directors present at the hearing further indicated that in striving for full operational maturity, particular attention will be given to:

- Reducing pre-mission formulation, planning, and training times,

- o Reducing post-mission turnaround times for the Orbiter and other elements of flight equipment,

- o Identifying and redesigning subsystems that require excessive maintenance, and

- o Reducing hardware production and overhaul costs.

From the testimony of the witnesses, it is clear that NASA has set definite goals that will have to be realized for each of the above areas in order for the STS to achieve full operational maturity. Less clear, however, is the extent to which NASA now knows specifically what must be done to achieve each of the goals. However, these matters are receiving substantial management attention by NASA and its contractors.

B. STS Organization and Management

Mr. Beggs and Mr. Moore emphasized the need for NASA to establish the proper organizational framework and management policies for future STS operations. Under this general category are issues concerning contract consolidation efforts, logistics management consolidation at a single field center, "fencing" Shuttle operations within NASA, and "spinning off" Shuttle operations to an organization outside of NASA.

On the subject of contract consolidation, Administrator Beggs stated that it is important for NASA to expand its consolidation of support services because these contract consolidations will further improve operational efficiency and will position the agency (or any possible future entity) to operate the STS with maximum economy and flexibility.

The Center Directors expanded on this subject, with Mr. Smith indicating that the Kennedy Space Center is now soliciting approval from NASA Headquarters to consolidate its cargo processing contracts. He stated that the number of contractors involved in cargo processing is not as great as those that had been involved in base operations and Shuttle processing. Therefore, the resulting savings from such a consolidation effort would likely be substantially less than are being achieved with the current consolidated Base Operations Contract (which he indicated was producing annual savings of 14 percent) and the Shuttle Processing Contract. However, Mr. Smith believes that some savings are possible.

In a similar vein, Mr. Griffin indicated that the Johnson Space Center currently has three activities underway to streamline its STS organization and management structure. They include:

- o A plan to consolidate in early 1986 the contracts that support the Operations Directorates in such areas as pre-mission planning, direct mission support, maintenance and operations of facilities, and sustaining engineering for facilities,

- o A plan to consolidate JSC's Flight Equipment Processing contracts that provide for the maintenance,

flight preparation, and inventory control of the equipment that flies with the Space Shuttle crew, and

- o A plan to consolidate and streamline the functions that are provided by the National Space Transportation System Office and the Space Shuttle Project Office (with the design and development personnel released by these actions made available to the Space Station program).

Mr. Griffin stated that in the process of implementing the last consolidation effort, JSC will consider transferring a number of logistics management functions to KSC. Earlier in the hearing, Mr. Moore had indicated that eventually, in the interest of economy, all logistics management responsibilities would be consolidated at KSC. Currently, logistics management responsibility for the Orbiter resides at JSC, while KSC oversees logistics matters for Space Shuttle ground support equipment and Marshall Space Flight Center is responsible for logistics oversight of the Space Shuttle Main Engine, Solid Rocket Booster, and External Tank.

The witnesses devoted considerable attention to the subject of "fencing" Space Shuttle operations within NASA (i.e., clearly separating the personnel, budgets, and facilities that support Space Shuttle operations from the rest of NASA's programs). This idea stems from a recommendation by the NASA Advisory Council contained in its "Mission of NASA"[1] study that NASA create a new organization within the agency headed by a Deputy Administrator to handle STS operations with "fenced manpower, finances, and facilities." Mr Anders, speaking for the NASA Advisory Council, indicated that NASA's separation of Space Shuttle operating funds from research and development, and procurement funds beginning with the FY 1985 budget, goes halfway to achieving the fencing that the Advisory Council recommended. According to Mr. Anders, the Council is pleased with NASA's action on this matter, but would like to see the agency move further in the direction of fencing Shuttle operations. However, he did not specify just what this might entail.

Mr. Beggs testified that he thought NASA could successfully fence Shuttle operations, but not before technical problems expected during the current phase of Shuttle development are resolved. The Center Directors agreed that some additional steps could be taken and that extensive fencing should not be implemented while research and development problems are being experienced. However, the Center Directors went a step further, expressing strong feelings that it would be a serious mistake to fence Shuttle personnel because it would impair NASA's flexibility to utilize its personnel efficiency and effectively in response to problems that might arise. Some felt that the Shuttle program would

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[1] NASA Advisory Council Study of the Mission of NASA. (Conducted by the NAC Task Force for the Study of the Mission of NASA, October 12, 1983).

always involve a research and development aspect and thus, unexpected problems. Other Center Directors believed that even if the program did not retain a research and development flavor, management flexibility should be retained to such an extent that personnel throughout the agency can be assigned to the program in a "matrix" fashion (i.e., to flexibly assign personnel with specific backgrounds or skills to the programs that are in most need of those specific backgrounds or skills) if and when operating problems develop.

Following the hearing, Mr. Stewart of the Aerospace Safety Advisory Panel submitted a letter that more fully explained the Panel's views on fencing Shuttle operations. He expressed the belief that Shuttle operations can be directed most effectively by an entity within NASA with the principal mission of achieving operational maturity. Accordingly, research and development efforts that are intended to expand the capabilities of the Space Shuttle could be managed by NASA's research and development centers rather than the operating entity.

To help resolve these issues regarding the extent to which Shuttle operations should be fenced, Mr. Beggs announced the creation of a Shuttle Operations Strategic Planning Group. The group will be headed by Robert Smylie (past NASA Associate Administrator for Space Tracking and Data Systems) and will report to the Administrator by the end of this year. Mr. Beggs indicated that this new planning group will also address the broader issue of if and when Shuttle operations should be "spun-off" or divested from NASA. Possible alternatives to NASA's operation of the Space Shuttle include transferring this function to either another governmental organization, a quasi-government corporation, or to the private sector. Specifically, the group will identify and assess the institutional, financial, business, regulatory, legislative, national security, management, and organizational arrangements associated with various options for future operation of the Space Transportation System.

All witnesses seemed to agree that the successful spin-off of Shuttle operations from NASA would not be possible before the late 1980s or early 1990s because the system would just not be financially and operationally mature enough before that time. Moreover, several Members of the Subcommittee questioned the wisdom of privatization of Shuttle operations before the development of a replacement system (referred to by NASA as a second-generation Shuttle or simply "Shuttle II"). For example:

- Both Mr. Volkmer and Mr. Nelson raised the national security sensitivities of having a key defense-related system managed and operated by the private sector, and

- Mr. Lujan observed that through the 1990s the U.S. government will account for over two-thirds of the Space Shuttle's flights. Since the U.S. government will be the major user, he observed "it doesn't make sense necessarily to have a commercially operated Shuttle."

(The Subcommittee also notes that NASA has always operated its own space transportation systems and in past years this has involved levels of flight activity as high as 34 launches per year.)

C. Launch Rate Trends

During the first day of hearings, Mr. Volkmer observed that the Space Shuttle has been having some difficulty in actually flying the number of missions that have been planned. He noted that of the 10 flights planned for FY 84, NASA will complete only four. Mr. Beggs and Mr. Moore testified that most of the recent flight cancellations have not been the fault of the Shuttle, but have been a result of problems with upper stages such as the Inertial Upper Stage (developed by the Air Force) and Payload Assist Module (that was commercially developed). Thus, the point is that even if the Space Shuttle itself experiences no operating problems, it is still possible for actual flight activity to be far below planned flight levels.

Looking to the future, all of the NASA witnesses expressed confidence that Shuttle operations will have matured sufficiently by 1989 to provide up to 24 flights per year. However, Mr. Moore differentiated between available capacity and actual demand, indicating that actual demand could be well below available capacity. Mr. Moore stated that, if one takes a pessimistic view, actual launch rates for the late 1980s could be as much as 25 percent below current projections (or in the range of 15 to 18 flights per year). The most optimistic view would place actual flight rates at one or two flights above the current projections of 21 to 24 flights per year. Mr. Moore also noted that NASA is considering differentiating in its operating budgets between available STS capacity and actual demand. This will permit the Congress to more readily distinguish between these two parameters and will notify customers when unused STS capacity is available.

The witnesses noted a number of factors that can cause actual demand to be less than projected. The disruptions and flight cancellations that can arise when problems develop with upper stages have been quite obvious in recent years. Additionally, Mr. Beggs observed that there is currently a sizable over capacity of communications transponders on orbit which is having a moderating effect on user demand to place additional spacecraft into orbit. Also, Mr. Beggs described the uncertainty regarding Defense Department intentions with respect to ELVs. The Air Force currently plans to replace two Space Shuttle flights each year with ELVs but Mr. Beggs and some Members of the Subcommittee expressed concern that DOD use of ELVs could actually be greater, and consequently, could produce a major impact on the Space Shuttle program.

As another complicating factor, Mr. Aldridge indicated that it will not be unusual for DOD to cancel planned Space Shuttle flights. He explained that the Defense Department must commit itself to launching satellites years in advance and therefore bases its launch projections on anticipated satellite failure rates. However, DOD has found that satellites frequently last much longer than anticipated. Consequently,

the launches of replacement satellites are delayed until the orbiting spacecraft they are designed to replace actually fail.

All of these factors make it quite difficult for NASA to accurately project actual flight rates years in advance. However, with time, as NASA and users increase their experience base with the Shuttle, the gap between actual and projected flight rates could narrow appreciably. Additionally, as the Space Shuttle matures, if it is possible for NASA to further increase the Shuttle's flexibility, user cancellations will become less of a problem.

D. Government Use of ELVs

Ever since the Air Force first announced this past winter that it was planning to develop and use ELVs as a "complement" to the Space Shuttle, several Members of the Subcommittee have consistently opposed the idea. In his testimony, Under Secretary Aldridge justified the DOD proposal citing the military necessity for having a backup to the Shuttle in order to remove a "single mode vulnerability" and give the Defense Department an "assured access to space." Mr. Aldridge argued that the new ELV would:

- o Provide a modest hedge against unanticipated and unforeseen Shuttle problems that might cause fleet groundings or outages,
- o Provide launch-on-demand flexibility to DOD for key national security programs,
- o Act to reduce DOD launch-on-demand pressures on NASA,
- o Retain an industrial base for U.S. launch-systems that would otherwise disappear, and
- o Maintain a viable international competitive capability for the U.S. in the ELV market.

Members of the Subcommittee raised a number of counter-arguments:

- o Mr. Volkmer pointed out that the Air Force has never had a backup to its Titan launch vehicles and observed that since both the Shuttle and the new ELV would employ the same upper stage (Centaur), the Air Force access to space would still be vulnerable at a single node.
- o Mr. Nelson's questioning of Under Secretary Aldridge revealed that all of the current Air Force arguments had been made before, but in 1978 the President decided that the U.S. Government would be committed to Shuttle use only.
- o Mr. Brown argued that the most pressing national security need is the ability to promptly replace low

altitude intelligence satellites in polar orbit and not the satellites in geosynchronous orbit that the Air Force ELV is intended to serve.

- Mr. MacKay questioned if the Air Force was not simply trying to produce its own launch vehicle empire so that it would not have to use NASA's.

At the hearing, Mr. Beggs indicated that he could not "gainsay the need of the DOD to have an assured launch capability." However, he felt strongly that the obvious candidate to provide this backup capability is a Shuttle-derived vehicle. He indicated that such a system could make cost-effective use of existing Shuttle production and launch facilities and personnel, and would implement the first step toward the development of a Shuttle-derived heavy-lift launch vehicle that Mr. Aldridge indicated could be required by the Defense Department sometime after 1992 for use in the strategic defense program. It was Mr. Beggs' view, though, that the Shuttle-derived ELV candidate that NASA will formally propose in response to the Air Force Request for Proposal "will not get a good hearing" by the Defense Department.

In response to Mr. Beggs' remarks, Under Secretary Aldridge claimed that the Defense Department is prohibited by Federal regulations from accepting a bid from a government agency that is in competition with a bid from a commercial firm. On the other hand, Under Secretary Aldridge indicated that DOD was trying to avoid that particular conflict by being as fair as possible in evaluating the competing proposals. He noted that he was hoping that a commercial firm would submit a responsive bid for a Shuttle-derived launch vehicle, but none has done so.

Mr. Beggs also explained that he felt that there would be a strong temptation for the Defense Department to increase its ELV use once the system was developed. He argued that since the cost to DOD of using the Shuttle will be fixed, the Defense Department could figure that by doubling their use of ELVs they could effectively cut in half the ELV's high overhead base. This would minimize DOD's cost of placing payloads into space, but as a result, the Space Shuttle program would suffer due to reduced flight rates and increased average cost per flight. On the other hand, Mr. Beggs stated that as long as the DOD keeps its ELV use to no more than two flights per year, NASA could sustain the loss in flight rate without a severe impact.

It is noteworthy that several members of the Civil Users Panel made arguments in favor of maintaining an ELV backup capability that were quite similar to those voiced by the Air Force. Mr. Michael Lyons of Satellite Business Systems testified that his firm has a "fundamental preference" for using the Space Shuttle as its principal launch vehicle. However, he indicated that his firm's decisions were principally driven by conservative business practices. Therefore, since past ELV experience has demonstrated that launch vehicles periodically sustain extended delays to recover from failures or damage to vehicles or launch support facilities, and since Shuttle operations are of necessity driven by an overriding concern for crew safety, SBS decided that it

was imperative for the firm to become familiar with an alternative launch vehicle that would permit SBS to launch its satellites in a timely manner even if the Shuttle is grounded for an extended period of time. Because of its past experience with the Delta, SBS would prefer this vehicle as a backup to the Shuttle. However, because of its concerns that the Delta may not be available in the future, SBS's conservative business practices led the firm to decide to become familiar with another backup vehicle--the European Ariane. Therefore, SBS has scheduled an Ariane launch for late 1986.

Mr. John Almond of Telesat Canada echoed Mr. Lyon's remarks by stating that he "thinks Telesat also would like to see a continued ELV availability just in case of a catastrophic failure that might hold up launches of the Shuttle for a prolonged period of time." Mr. Almond also indicated that his firm's choice of a launch vehicle would be heavily influenced by factors such as price and the availability of attractive financing. Mr. William Ziegler of Western Union expressed some past about the schedule reliability of the Space Shuttle, but stated that economics would probably play the greatest part in Western Union's decisions regarding which launch vehicle to use. In fact, Mr. Ziegler went so far as to indicate that if all other things (such as price and reliability) were equal, "Western Union would much prefer to go on a Delta launch vehicle" rather than the Space Shuttle. (Note, his reasons for this view are discussed in the next topical area of this Section.) Mr. Gilbert Moore of Morton-Thiokol concluded by observing that the Delta is also more desirable for placing some kinds of satellites into polar orbit.

Mr. Bill Anders of the NASA Advisory Council added additional weight to the views of the representatives of the civil users community, by stating that both the NASA Advisory Council and the Task Force on Effective Shuttle Utilization headed by Edgar Cortright had concluded "that there should be a backup capability in this early stage of Shuttle development." He went on to testify that "whether that's done by the Air Force, by NASA, commercial activity, or all of the above, is of much less interest to (him) than the fact that we do have some backup, because the Shuttle is an immature system." In subsequent questioning, Mr. Anders indicated that it may be desirable to assure the availability of a backup launch capability until the Shuttle is "fully operational" (which NASA indicated will be 1989), and possibly until the late 1990s or after the year 2000.

E. User Perceptions

A principal objective of the hearings was to determine how adequately and efficiently the Space Shuttle fulfills user needs and to solicit recommendations on how Shuttle operations could best be improved to benefit users. Under Secretary Aldridge provided the DOD perspective and the Civil Users Panel provided the views of the civil user community.

In his testimony, Under Secretary Aldridge stated that he is "pleased to note that all performance requirements appear achieveable for (Shuttle) missions to be launched from the Kennedy Space Center." However,

he expressed some concerns with the Shuttle's lift capability from Vandenberg Air Force Base, but indicated that the system improvements that NASA has under development should soon give DOD the lift capability that it requires. He went on to add that all other DOD payload-unique requirements (including security and communications requirements) should be met. Thus, his statement made clear that the Defense Department continues to be supportive of the Space Shuttle and apparently has no major concerns regarding the capabilities of the STS. On the other hand, the NASA Center Directors later expressed the view that the Air Force may in fact not yet be fully comfortable with the capabilities of the Space Shuttle. Mr. Griffin expressed personal disappointment that the DOD still looks upon the Shuttle as an unmanned vehicle, and is therefore not taking full advantage of the unique capabilities of the system. Mr. Griffin added that he thought the principal problem is that NASA has been delayed in flying a fully dedicated DOD mission. He went on to explain that every Shuttle customer has been a bit apprehensive before their first flight, but after completing a mission they are satisfied and become very enthusiastic. He concluded, therefore, that once the DOD has flown a dedicated mission or two, they will become comfortable with the system and will realize that it provides them with a new capability. At that point, he believes there will be an acceleration of DOD interest in using the Shuttle to its fullest extent. Each of the Center Directors concluded by characterizing their working relationship with counterparts in the Defense Department as excellent.

The panel of civil users began by indicating that they believe that the Space Shuttle is an excellent, reliable, and flexible launch vehicle, but continued by citing several disadvantages of the STS:

- o The amount of manpower that a user must dedicate to supporting a Shuttle launch is more than double that required to support an ELV launch,
- o Shuttle users must interface with a more geographically disperse group of government offices than users of ELVs,
- o The time and amount of documentation required to integrate a payload on the Shuttle is substantially greater than that required for ELVs, and
- o There is substantially more flexibility in rescheduling launches on ELVs than on the Space Shuttle.

Additionally, the users indicated that they find little value from the in-flight checkout of a spacecraft and manned interaction that the Shuttle provides. Most of the civil users also found little value in the Shuttle's recovery and repair capabilities as well as the opportunity it affords a customer to give a "last minute no" regarding the deployment of a spacecraft from the Shuttle. (This could largely be due to the fact that spacecraft manufacturers have not yet begun to build satellites that take advantage of these Shuttle-unique characteristics.)

The users summarized their views by expressing a belief that "it will always be a more difficult operation to launch on a Shuttle than on a typical expendable launch vehicle." On the other hand, they indicated that NASA has been working hard to respond actively and positively to the concerns of customers in order to make the Space Shuttle more "user friendly."

The STS improvements suggested by the users included the following:

- o Documentation procedures should be simplified and standardized,
- o Processing time should be shortened,
- o Overall mission complexity should be reduced,
- o NASA's ability to rapidly reconfigure payload manifests should be enhanced,
- o The burdens imposed by safety requirement reviews and payload processing operations should be reduced,
- o The relaunch provisions of the Launch Service Agreement should be improved, thus making it easier for a user to make a "no-go" decision, and
- o Shuttle operations should be centralized at the Kennedy Space Center.

Finally, Mr. Ziegler of Western Union strongly recommended that the government institute an independent review function to continuously review the design, manufacture, qualification, and test of all propulsion systems designed and manufactured within the United States. He indicated that these reviews should be quite similar to the Flight Readiness Reviews that the Goddard Space Flight Center used to hold for Delta launch vehicles. He observed that in the fields of electronics and communications sytems, the user firms have adequate personnel in-house to provide the required oversight function. However, these firms find it impossible to attract or retain the necessary talent to perform the required oversight function for propulsion systems. Mr. Ziegler concluded by stating that he supports the commercialization of ELVs and upper stages, but believes that all parties involved would benefit if the Federal Government would provide a propulsion system review and flight readiness approval function. Under questioning by Mr. Volkmer, Mr. Ziegler indicated that it would be acceptable to have the user community pay for this service and he felt that the U.S. Government should not be held liable if a "certified" vehicle or upper stage were to fail.

F. Orbiter Turnaround Times

If the Space Shuttle is to be able to achieve the maturity and high launch rates planned by NASA, Orbiter turnaround times will have to be

substantially reduced. In response to a written question from the Subcommittee, Mr. Moore indicated that the initial turnaround time for each new Orbiter has been greater than 100 workdays, but has been reduced to as low as 53 workdays for OV-99 on STS 41-C. NASA's current plan is to demonstrate an Orbiter turnaround capability of 35 workdays during fiscal year 1985. Over the next two or three years, NASA's goal is to further reduce turnaround time to 28 workdays.

Mr. Moore indicated that the original design goals of a 10 workday turnaround time for the Orbiter would not be achieved. Later, Charles Gunn, Director of Shuttle Operations at NASA Headquarters summarized by stating that all of the planning, facilities, and funding required to achieve a 35 workday turnaround time are now in place.

Finally, Mr. Volkmer asked the Center Directors to identify the most serious current constraints on Space Shuttle launch rate. Mr. Smith indicated that he thought it was the lack of a large backlog of payloads ready to go into orbit. Later, he expanded on this point to state that the motivating effect a payload backlog would have on his people would be substantial, and, as a result, new and innovative solutions to turnaround problems would be found. In his initial response, Mr. Griffin indicated that he thought the major constraint is a current shortage of available upper stages. He went on, however, to expand his answer to state that NASA has also been having some problems with the basic Shuttle itself.

In his prepared statement, Mr. Smith included a detailed discussion of the steps required to reduce turnaround times. It is his view that an increased level of maturity will have to be achieved in a number of areas, including:

- o Maturity in flight hardware and software, reflected by: (1) a reduction in the number and frequency of modifications; (2) a substantial reduction in the amount of time involved in testing; and (3) increased confidence in routine processing,

- o Maturity in flight hardware logistics so that the right parts are available when needed and these on-the-shelf parts are readily accepted for use without extensive verification testing and management interaction, and

- o Maturity in flight hardware processing through the establishment of new work procedures.

Mr. Smith indicated that the new work procedures that will be adopted at KSC include:

- o Standardizing the process flow,

- o "Stationizing" the workforce, so that the work flows to the worker rather than the worker moving to the work, and

- o Optimizing processing operations, including the adoption of product improvements and facility modifications.

A series of questions were asked of Mr. Moore and Mr. Griffin to determine why so much time is required to compile and verify the software package for each mission. They explained that the software for every cargo element (each with several on-orbit launch options) has to be compiled and verified individually, and then the entire payload package must be exercised in unison. Second, the trajectory shaping required to fly the Shuttle through the atmosphere is a very complex and involved process. Finally, all elements of the flight software must be verified, in real time, by hand, by the ground crew, flight crew, and customers who will be involved in the mission. Mr. Griffin indicated that though the time required to accomplish all of this is still substantial, it has been significantly reduced. Mr. Moore added that these times will be further reduced a great deal in June of 1985 when the flight software production process is automated.

G. Operating Costs

The NASA witnesses emphasized that one of the agency's major goals is to bring down the cost of operating the Space Shuttle. Mr. Beggs reported that NASA has made excellent progress in recent years in lowering Shuttle costs and he was certain that such progress would continue in the future.

Mr. Moore indicated that the total average cost of operating the Shuttle has grown substantially from estimates that were compiled early in the program. In 1976, Shuttle costs were projected, based on a 12-year period involving 572 missions, to average $18 million per flight (in constant FY 1975 dollars). Currently, NASA estimates that the Shuttle will make 227 missions during its first 12 years of operation and that costs will average about $60 million per flight (in constant FY 1975 dollars). Mr. Moore stated that this cost growth is primarily due to the reduced level of flight activity projected in 1976 versus the current mission model. (However, now that NASA has compiled a cost data base from actual Shuttle operating experience, it is clear that earlier projections of operating costs were overly optimistic even for the high flight rates that were assumed.)

The NASA witnesses cited a number of efforts that are underway to lower operating costs. These include:

- o Productivity improvement programs to lower the unit cost of recurring production hardware,

- o Research and development programs to extend the operating life of major components such as engines,

- o Contractor consolidation efforts at NASA field centers,

- o Contractural incentives to encourage firms to achieve additional manufacturing and processing cost savings, and

- o The adoption of modified accounting procedures that will allow NASA to better determine the overhead and support costs being charged by hardware suppliers.

Both Mr. Beggs and Mr. Moore emphasized the relatively large size of the fixed operating base (i.e., those costs that do not change with variations in launch rate) required to support the Space Shuttle. Mr. Moore indicated that even at a launch rate of 24 flights per year, more than 60 percent of the Shuttle's total operating budget is required to support the fixed costs. For lower launch rates, fixed operating costs account for an even larger percentage of the Space Shuttle's budget. For example, additional information submitted by Mr. Moore, indicated that at a launch rate of three to four flights per year, fixed operating costs account for about 90 percent of the Shuttle's total budget.

The large size of the Shuttle's fixed operating base has the effect of making the Space Shuttle's total average operating cost (i.e., total annual cost divided by the number of flights) highly sensitive to changes in annual flight rate. For example, Mr. Moore submitted data indicating that (in constant FY 1982 dollars) an average Shuttle mission costs $353 million if flown at a rate of four flights per year; $197 million at eight flights per year; and $91 million at 24 flights per year. (Mr. Beggs had explained that a major part of this cost variation is due to the fact that the cost of the large fixed-operating base is being distributed over a variable number of annual flights.) On the other hand, if these total average costs are broken down into their fixed and variable components, cost data submitted by NASA and briefings given the Subcommittee staff by NASA officials prior to the hearing indicate that:

- o The total size of the Shuttle's fixed operating cost varies little with changes in launch rate (especially if the capacity to support 24 missions per year is retained), and

- o The variable (or marginal) cost of each additional flight added to the manifest also changes very little over a wide range of launch rates (e.g., between 8 and 24 flights per year).

Thus, over a wide-range of flight rates, both the fixed cost of supporting the basic Shuttle infrastructure and the variable cost of each new flight added to the manifest are relatively constant. However,

when total Shuttle operating costs are quoted in a manner that spreads the large fixed operating base over the particular number of flights accomplished in any given year, they become highly sensitive to flight rate.

H. Pricing Policy

Because of the broad and significant ramifications of the Space Shuttle pricing policy now under development for the 1989-1991 time period, much attention has been given to this issue. Accordingly, at the hearing a number of questions on this subject were posed to the witnesses.

A major part of the pricing policy debate has centered on whether NASA should charge users "additive cost" (sometimes also referred to as "variable cost" or "marginal cost", and defined as the additional cost that must be incurred in adding a flight to the manifest) or "total average cost" (which mainly differs from additive cost in that it includes an equal pro rata share of the fixed cost of operating the STS). Thus, the key policy question is whether commercial users should pay a share of the Shuttle's fixed operating cost. Though many of the witnesses were in favor of charging commercial users only additive cost, there was disagreement on whether this would constitute a subsidy of commercial users. Most witnesses referred to prices based solely on additive cost as being subsidized. However, other witnesses, such as Mr. Griffin, observed that with additive cost pricing, commercial users would be paying all of the costs that the government must incur over and above those required to support the government's own basic program. Building on this logic, Mr. MacKay argued that since a user would be fully reimbursing the government for all expenses incurred by the government in adding a flight to the manifest, additive cost pricing does not actually constitute a subsidy.

In expanding on a point made by Mr. Moore, Mr. Isaac Gillam (NASA's Assistant Associate Administrator for Customer Relations and Policy) indicated that there are four basic factors that NASA will consider in recommending a price for commercial and foreign users:

- o The impact of the pricing decision on private sector initiatives, including ELVs and upper stages,
- o The impact of the pricing decision on other high technology space commercialization initiatives such as materials processing,
- o The impact of the pricing decision on foreign competition such as with the Ariane, and
- o The impact of the pricing decision on the STS budget.

In response to a written question, Mr. Beggs summarized NASA's view of the advantages and disadvantages of "additive cost pricing" and "total cost recovery pricing" (i.e., charging "total average cost") as follows:

"The purely additive cost recovery policy which is not now being implemented would allow for an internationally competitive price and also permit the industrial entrepreneuers to develop or improve technology and products with some extensive, but not excessive risk of capital."

"Total cost recovery would provide for the commercial customer to pay a pro rata share of the total costs to the U.S. Government. However, the resulting price may be non-competitive for the current spacecraft satellite customers and might result to be too expensive to encourage the developers of new space-based products. (Also), a significant increase in pricing may actually increase the cost of maintaining the Shuttle program depending upon the number of customers lost."

To put these policies in some perspective, Mr. Moore estimates that the additive cost of a Shuttle flight is about $43 million (in constant FY 1982 dollars). By contrast, total average cost for the period beginning 1989 is projected by NASA (assuming a 24 per year flight rate) to be about $91 million per flight (in constant FY 1982 dollars). One possible middle ground between these two extremes would be a continuation of the current 1986-1988 price of $71 million per flight (in constant FY 1982 dollars).

Other witnesses raised additional issues that should be considered in establishing a new Shuttle pricing policy:

- Mr. Griffin argued that the price should be stable, and known to users well in advance. He felt that the Shuttle should be viewed as an "instrument of national policy" and that the pricing policy should be set to maximize the exploitation of the unique capabilities that the Shuttle offers to this country and our allies. Mr. Griffin also expressed some concern that the adoption of the wrong pricing policy could put the Shuttle on a "death spiral" where high costs drive users to competing systems, thus lowering flight rates, which in turn causes total average cost (i.e., where fixed overhead costs are pro rated among each flight) to go up, which further drives up user fees, causing additional users to drop off the manifest, et cetera.

- Mr. Anders testified that the Shuttle should be viewed as a "national resource" that has value for manned spaceflight, defense missions, space science support, research and technology development, satellite retrieval and repair, and international activities. He indicated that the costs associated with the national resource value of the Shuttle should be borne by the government and not by other users.

- Mr. Anders further expressed the view that the principal value of any transportation system is the new frontiers it can open up and the increased economic activity it can spawn. Mr. Anders observed that because of these benefits, the government has in one way or another chosen to subsidize all other modes of civil transportation (e.g., ship, rail, truck, air). Space transportation, he felt, should be no different.

- Mr. Anders also quoted a conclusion of the NASA Advisory Council's "Mission of NASA"[2] study that incremental cost pricing should be used for the Shuttle because that is the type of pricing that NASA has adopted for commercial use of its research facilities. (Additionally, it can be noted that this is the same pricing policy NASA and DOD have adopted for commercial ELV use of government launch facilities.)

- Mr. Lyons of Satellite Business Systems observed that a number of the operational capabilities designed into the Shuttle were intended to support special DOD or NASA requirements. It is his belief that, to the extent these capabilities add to the complexity and operating costs of the Shuttle, those increased costs should not be charged to commercial users.

- Finally, each of the commercial users expressed the view that the extent of the ultimate commercial success of their services or products will be closely tied to the cost of space transportation.

In addition to their views regarding the basis upon which Shuttle prices should be established, some witnesses also made additional pricing policy suggestions (not all necessarily consistent with one another) for consideration by NASA and the Congress:

- Mr. Ziegler of Western Union suggested more frequent but smaller price changes. Other members of the Civil User Panel agreed and suggested that a one-year time horizon would be a reasonable frequency.

- Mr. Almond of Telesat Canada recommended that a basic Shuttle price should be set each year and then that price (adjusted for inflation) should hold for all launch agreements formally committed to in that year, irrespective of when the launch is scheduled to occur.

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[2] NASA Advisory Council Study of the Mission of NASA, (Conducted by the NAC Task Force for the Study of the Mission of NASA, October 12, 1983).

Standard government inflation factors would be used to adjust the launch price from the year that the agreement was signed to the year that the flight occurs.

- o Mr. Pace of Microgravity Research Associates suggested that the pricing policy permit deferred payments; that NASA consider more than one class of fare for Shuttle users; and that NASA provide users with pricing forecasts for the "out years" (e.g., 10 to 15 years in the future).

- o Finally, Mr. Anders of the NASA Advisory Council suggested that NASA review its postponement policies with the intent of reducing the penalties for postponements caused by commercial users; and that NASA review and improve its discount policy for standby payloads.

In addition to NASA's commercial pricing policies, the Members of the Subcommittee also reviewed possible modifications to the DOD pricing policy. Mr. Beggs explained that the DOD currently pays none of the fixed costs of operating the Shuttle (a policy that he thinks should continue) and that there is no penalty or cancellation fee that is charged DOD when they cancel a flight (a policy that he thinks should possibly be changed). He indicated that he thought it would be fair for DOD to be assessed a non-refundable "standby charge" when they reserve a flight on the manifest. This standby charge could be made equal to the non-recoverable expenses that NASA must incur in setting up a flight. In this way, NASA would not suffer financially when DOD cancels a Space Shuttle mission. The implementation of such a standby charge would be especially beneficial to commercial users if NASA adopts total cost recovery as a commercial pricing policy, because without such a fee, the cost to all commercial users could increase significantly each time the Defense Department cancels a flight. (On the other hand, if NASA were to base its user charges on available capacity rather than actual flight rate, prices charged to commercial users would be unaffected by changes in DOD flight activity.)

Under Secretary Aldridge responded that the suggested standby fee would wrongly "penalize (him) for success"--i.e., the typical reason why a DOD flight is cancelled is that an orbiting satellite that had previously been scheduled for replacement is still operating in a healthy manner, so no replacement is necessary. Mr. Volkmer asked the Under

Secretary if no standby fee is paid, would not the Defense Department be penalizing NASA when it cancels a flight? Mr. Aldridge responded that it would not really matter because "the taxpayer will pick up the total cost whether DOD pays it or NASA pays it" and that therefore "it doesn't make any difference whose budget it is in."

I. Need For Additional Orbiters

Debate over the need for a fifth Orbiter has continued for years. The Subcommittee is on record as being in favor of the production of this vehicle.[3]

Mr. Griffin observed that those on the implementing side of the space-flight business "would all agree that a fifth Orbiter would certainly be a nice thing to have." He conceded, however, justification for the need for the vehicle may be difficult to obtain on the basis of the current launch manifest. Nevertheless, he recommended "a robust Shuttle fleet" noting that a four Orbiter fleet does not leave much margin for increased demand or unforeseen difficulties.

Mr. Moore testified that with the availability of the Space Station and the commercial activities it could spawn, future demand could justify the need for a fifth Orbiter. He noted, however, that if this vehicle is going to be built, a decision to do so should be made soon. Otherwise, the loss of prime and lower-tier contractors will make the vehicle substantially more expensive to manufacture. Mr. Moore indicated that the current structural spares program will carry some contractors through FY 1986. However, a number of second- and third-tier contractors will begin to phasedown in late FY 1985.

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[3] The Need For An Increased Space Shuttle Orbiter Fleet. Report. Committee on Science and Technology, U.S. House of Representatives, 98th Congress. Serial HH, December 1982.

Authorizing Appropriations to the National Aeronautics and Space Administration for Fiscal Year 1984. Legislative Report #98-65, April 15, 1983.

Authorizing Appropriations to the National Aeronautics and Space Administration for Fiscal Year 1985. Legislative Report #98-629, March 21, 1984).

The National Aeronautics and Space Act of 1958. Report. Committee on Science and Technology, U.S. House of Representatives, 98th Congress. Serial EE, September 1984.

Finally, the Subcommittee inquired as to whether it might be necessary to build "replenishment" Orbiters to replace existing vehicles as they wear out. Mr. Moore noted that although the Orbiters were designed to make 100 flights, the major load-carrying structures of each Orbiter is designed to be capable of surviving without failure for a total of 400 flights. Thus, as long as NASA is able to replace operating systems and components on board the Orbiters with replacement spares, the existing Orbiter fleet should be capable of supporting U.S. space transportation needs for many more years. Mr. Moore also indicated that vehicles eventually built to replace the existing Orbiters could be significantly different in design, as new technologies and processes would then be available.

J. Hardware Improvements

In the course of the hearings several witnesses addressed the issue of what hardware improvements are required to bring the Space Shuttle to full operational maturity and whether additional improvements should be made to extend the capability of the Space Transportation System beyond current design requirements. Mr. Beggs mentioned: improvements that are being developed for the main engines; the development of the light weight case for the Solid Rocket Booster; and further weight reductions that are necessary in other systems in the Shuttle. He also noted that the main computer processors are probably going to have to be replaced because they represent 15 year-old technology and it will become increasingly difficult to find hardware to maintain them.

In his testimony, Mr. Moore explained that the wings on Orbiters OV-103 and OV-104 are being strengthened; OV-99 and OV-104 are being modified to accommodate the Centaur; a fifth Cryogenic Tank Set is being added to OV-104 to increase its on-orbit stay time; the Orbiter's brake and APU systems are being improved; studies are underway to define the systems or hardware required to provide rapid turnaround of payload command and data system software; and NASA is considering making improvements in the Orbiter's Inertial Measurement Unit and in the Redundant Vernier Reaction Control System Thrusters.

Mr. Moore explained that the improvements NASA currently has planned or under evaluation are primarily aimed at enhancing current systems rather than making large scale improvements in capabilities such as on-orbit stay time and available electrical power. Mr. Griffin testified that future system changes should be limited to those required to reduce turnaround time and operating costs. Mr. Moore added, however, that within the next 10 to 15 years NASA may move to extend the Orbiter's overall performance by increasing available electrical power and on-orbit stay capability. In Mr. Moore's view, barring a catastrophic loss of an Orbiter, the Space Shuttle will be able to meet all user needs over the next 10 to 15 years.

Looking into the future, Under Secretary Aldridge testified that by the mid 1990s the Defense Department will need a new class of heavy-lift vehicle. Accordingly, he noted that the Air Force budget for 1985

included $2 million to begin a study effort for this vehicle and he explained that DOD is working closely with NASA through the Aeronautics and Astronautics Coordinating Board to define joint requirements for such a heavy-lift system.

K. Second Generation Space Shuttle

Members of the Subcommittee have expressed an interest in future generations of the Space Shuttle. Accordingly, several witnesses were questioned on this subject.

Mr. Beggs testified that NASA is approaching the development of the next generation Shuttle in the same manner it approaches all new systems--namely, pursuing the necessary advanced technology in research laboratories with an eye toward the day NASA will design a new system. According to Mr. Beggs, NASA will begin to design an upgraded Space Shuttle sometime in the early 1990s.

Dr. Hearth explained that the development program for a vehicle like the Space Shuttle requires about 10 years and relies heavily on research activities initiated 15 to 20 years before. Although today's technology programs can have significant near-term payoff as enhancements for existing systems, he said they have the potential for the greatest leverage on new systems that will be introduced after the year 2000. He emphasized that it is critical for the United States to invest a reasonable amount of resources into the development of advanced technology.

Dr. Hearth further explained that the technological areas offering the greatest potential for reduction in the life-cycle cost of the next-generation Shuttle (referred to as Shuttle II) include: (1) structures and materials; (2) propulsion; and (3) aerodynamics. He noted that the current goal for the Shuttle II is to provide a major advancement in Earth-to-orbit transporation efficiency through lightweight and high performance engines; productivity advancements through rapid turnaround and reduced manpower; and cost reductions for all program phases through reusablility, long life, and increased use of automation in design and manufacturing as well as in operations. Dr. Hearth indicated that it may be possible for a Shuttle II with the same payload lift capability as the current Space Shuttle to be less than one-half the weight, require only one-week of ground turnaround time, and have only one-tenth the operations cost of the present Space Shuttle.

Dr. Hearth professed uncertainty over when and why Shuttle II will be developed. He indicated, however, that development of Shuttle II could be initiated as soon as the early 1990s. Mr. Volkmer observed that resource limitations would make it difficult to fund such a developmental effort at the same time that the Space Station is under development, which could delay the start of the Shuttle II development program until the mid or late 1990s. Given Dr. Hearth's estimate that such a development effort would require 10 years, a replacement to the existing Space Shuttle possibly will not be available for at least 20 to 25 years from now.

L. Spare Parts and Logistics Support

One of the most important factors affecting the operational maturity of the Space Shuttle is the availability of an adequate supply of spare parts. Mr. Griffin observed that in large development projects, resolution of logistics problems are commonly delayed when developmental problems arise. He indicated that this is what happened to the Space Shuttle and as a result an adequate inventory of replacement spares was not purchased early in the program.

Charles Gunn, Director of Shuttle Operations at NASA Headquarters, testified that with the recent support of the Congress this problem is well on its way to being solved. (This past year the Congress approved a major increase in the Shuttle's budget for spare and replacement parts.) However, because there is a two to three year lead-time between when spare parts are ordered and when they become available, Mr. Gunn indicated that there would continue to be spare part shortages through 1985 and 1986. After that time, adequate stocks of spares should be available.

Mr. Walt Dankhoff, who heads the Propulsion Division for the Space Shuttle at NASA headquarters, indicated that the spares situation for the Shuttle's main engine is also improving significantly. Mr. Dankhoff stated that there is currently only one spare engine that must be shared by all of the Orbiters, but by the end of calendar 1985 there will be a spare engine for each Orbiter in the fleet.

One indication that the situation is improving is the fact that the frequency of cannibalization of parts from other Orbiters is declining. This is significant because continued high levels of parts cannibalization among Orbiters in the fleet would make it difficult for the STS to achieve higher flight rates. Mr. Gunn testified that during the period from April through June of this year required Orbiter repair parts were available "on the shelf" 75 to 83 percent of the time. (By contrast, these figures used to average about 50 percent.) System-wide, monthly parts availability rates for the whole Shuttle program for this past April-June time period averaged between 80 and 93 percent.

Another dimension of the spares issue is whether operating components are achieving their original design lifetimes. Mr. Beggs testified that 80 percent of the subsystems onboard the Shuttle are lasting longer than NASA had originally anticipated. The systems with which NASA is having the greatest difficulty include the main engines (particularly their high-speed rotating machinery), the auxillary power units, and the central processing units of the main computer. Mr. Beggs indicated that there are research and development efforts underway to correct these problems, and emphasized that they do not pose a flight safety problem. He added that the question is not whether these systems will fail in flight, but rather with what frequency they must be overhauled or replaced to ensure their reliability.

There are several additional logistics-related issues that NASA is now attempting to resolve. As outlined by Mr. Moore, these include:

- o As Orbiter production draws to an end and production lines are shut down, how will the availability of spares be assured?

- o Whether and when logistics management responsibilities should be transferred to the Kennedy Space Center?

- o The advisability of creating a centralized repair and maintenance depot at the Kennedy Space Center for maintaining Orbiter flight hardware versus contracting this effort out to the private sector or DOD Air Logistics Centers?

M. Flight Safety

Both Mr. Moore and Mr. Stewart of the Aerospace Safety Advisory Panel emphasized that thus far the STS safety record has been 100 percent. Further, both indicated that the management systems required to protect this record are in place, and performing well.

Mr. Volkmer noted the conflicting nature of NASA's goals to reduce turnaround times and operating costs with its goal to maintain high quality and safety levels. He raised the issue of how NASA will keep these conflicting goals in balance? In response to this question, every NASA witness stated emphatically that ensuring product quality and safety is their highest objective and that the agency's goals to reduce turnaround times and operating costs are secondary by comparison. A number of the witnesses gave examples of the techniques that are and will continue to be used to ensure product quality and safety:

- o Mr. Griffin indicated that a key to operational success is maintaining "process control", so that unscrutinized or inadvertent changes and variations in materials, environments, procedures and processes do not creep into the system. He also emphasized the importance of constant vigilance and support by management.

- o Dr. Lucas noted that his field center employs a vigorous inspection system that includes periodic comprehensive Quality Readiness Reviews involving prime contractors, major subcontractors, delegated inspection agencies, and key government and contractor senior management personnel. As part of this program, contractors hold motivational meetings and reviews with their key subcontractors and suppliers. Additionally, Dr. Lucas indicated that his center has adopted contract provisions that impose substantial penalities for any defects in hardware that are discovered after delivery of the hardware or for any flight failures that result from improper hardware performance.

- o Mr. Smith stated that there is a culture that permeates the entire agency and its contractors in which employees are encouraged to surface problems and concerns. Employees are never penalized for reporting problems, but are sternly disciplined for failing to do so.

Mr. Stewart testified that there are a number of safety-related issues that concern the Aerospace Safety Advisory Panel, although none of these issues presently precludes conducting safe and successful Space Shuttle missions. Among the items being followed by the Panel are:

- o That NASA and its contractors maintain a high level of product quality,
- o The operational safety of the Solid Rocket Motors, including their steel and filament-wound case segments, and their nozzle subsystem,
- o The structural adequacy of the Orbiter,
- o The adequacy and reliability of hardware spares,
- o The safety risks to the Orbiter of upper stages that are carried in its cargo bay,
- o The Orbiter's brake failures that have reoccurred on a number of landings, and
- o The flight control characteristics of the Orbiter, especially its pitch control characteristics near the ground.

Mr. Stewart indicated that, as a result of its reviews, the Panel has also recommmended NASA pay particular attention to the following areas:

- o Assuring the continuity of necessary STS personnel and expertise,
- o Scrutinizing both continuing activities and modifications to assure that management maintains a thorough assessment and understanding of operational risks as the STS program becomes more routine,
- o Expanding the Shuttle's ascent and descent flight envelopes,
- o Maintaining appropriate planning and funding for critical support requirements, such as spare parts, and
- o Conducting careful assessments when accepting a single event accomplishment as proof of the capability of an element of hardware or software for either flight or ground support equipment.